105 Designing Artificial Bones

Engineers design many artificial body parts, including bones. Designing replacement bones for the human body requires understanding the important qualities of bone. Bones are strong enough to support muscles and tissues at rest and during exercise. They weigh surprisingly little, especially in animals that fly. They are also slightly flexible so that, under normal stress, they bend a little rather than break—the way tree branches do. To be useful in a prosthetic arm or leg, artificial bones must also be strong, flexible, and lightweight.

CHALLENGE

How can you design a prototype of an artificial bone that is strong, yet light and flexible?

MATERIALS

For each group of four

- **masking tape**
- **packing tape**
- **brown parcel tape**
- **transparent tape**
- **8 straws**
- **1 piece of paper or cardstock**
- **1 70-g mass**
- **1 metric ruler**

For each student

- **1 Student Sheet 105.1, "Initial Bone Prototypes"**
- **1 Student Sheet 105.2, "Refining Bone Prototypes"**

Design Requirements

You are an apprentice to a bioengineer. In preparing to design a bone for a human prosthetic limb, Dr. Chao wants to build a scaled-down model. She provides you with the following design requirements. The model must:

- be no longer or shorter than a drinking straw,
- contain exactly one straw,
- support at least 70 g without crimping,
- have a mass of no more than 7 g, and
- contain no rods, skewers, or wires.

PROCEDURE

Part A: Plan

1. Work in your group of four to develop a set of four artificial bone prototypes. Discuss your design ideas and decide which materials you will use. Then decide who will make each prototype.
2. On Student Sheet 105.1, "Initial Bone Prototypes," draw and label diagrams of your bone prototypes. At this point, you do not need to identify the exact amount of each material that you will need in your design.

Part B: Construct

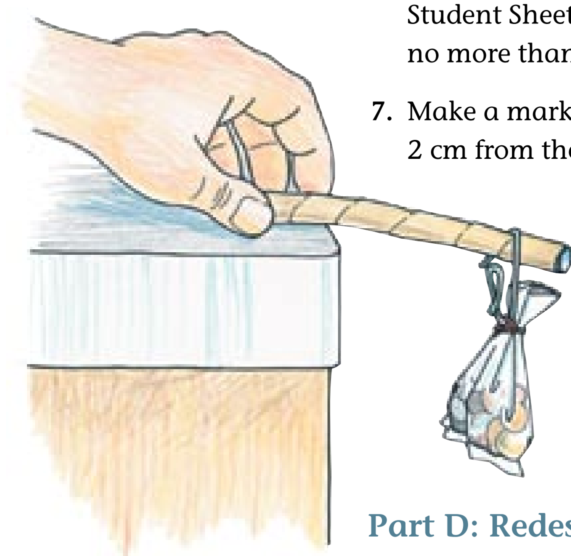
These students and their teacher are making an artificial limb in a community college class.

3. Make the initial prototype assigned to you by your group. Measure or count the amount of each material you are using. **Hint:** Try to use amounts that are easy to measure, such as 10 cm of tape. Measure all materials before you use them.
4. On Student Sheet 105.1, record the amount of each material you used on your diagram.
5. Have all group members share the initial prototypes within your group and make diagrams of your group members' work.

Part C: Test

6. Measure the mass of each initial prototype. Record the mass on Student Sheet 105.1. Remember, to meet the design criteria, it must be no more than 7 g.

7. Make a mark on each bone 1 cm from one end and another mark 2 cm from the other end.



TESTING PROCEDURE

8. Use the procedure demonstrated by your teacher and illustrated in the figure shown at left to test your group's initial prototypes' ability to support a 70-g mass. Record the results on Student Sheet 105.1.

Part D: Redesign and Refine

9. As a group, decide which prototype represents the general type of design you should develop further.

10. Discuss which variable you will investigate and test. For example, you might try varying the amount of tape or the type of tape. This is your experimental variable. You should keep all other variables the same; these are the controlled variables.

11. Exchange ideas about how to test the experimental variable. Develop another set of four prototypes. Draw labeled diagrams of your second set of prototypes on Student Sheet 105.2, "Refining Bone Prototypes." Highlight the experimental variable.

12. Build the four prototypes, working closely with your group members to be sure that the controlled variables are kept the same. Mass the refined prototypes and test them using the procedure shown in Figure 1. Record your results on Student Sheet 105.2.

Part E: Share Designs

13. As directed by your teacher, present your development process to the class. Include both a description of your procedure for constructing your prototypes and any conclusions you can draw based on the data you collected.

EXTENSION

Test your best prototype to see how much weight is necessary to make it fail. Your prototype fails when it crimps, creases, or bends and does not return to its original straight shape when you remove the weight.

ANALYSIS

1. a. Which of your refined prototypes was strongest?
   b. Which of your refined prototypes was lightest?
   c. Which of the class's artificial bone prototypes looks most promising for future development? Explain.
2. If you had more time and materials, what would your next design look like? Sketch and label it to show what changes you would make.
3. How might a light but strong tube be used, other than to replace bones? List at least three ideas.
4. a. How is the process that you and your group used for this project similar to and different from the process you used in Activity 104, "Designing Artificial Heart Valves"?
   b. How was the design process you just completed similar to and different from designing and conducting scientific experiments?